Combining InSAR and GNSS to model magma transport during the May 2016 eruption of Piton de la Fournaise Volcano (La Réunion Island).

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Dikes and Sills propagation lead to fissural eruptions

Eruptive Fissure, July 14, 2017, Piton de la Fournaise

Eruptive Fissures, July 13, 2018, Piton de la Fournaise
Magma transport at basaltic volcanoes

Magma can propagate tens kilometers potentially reaching inhabited areas and man-made infrastructures.

Eruptive fissures and lava flows, May 2018, Leilani Estate, Hawaii (USA)  
(Photos USGS)
Mitigating this risk implies a better understanding of what happens between the reservoir and the surface.
An active and well monitored volcano

18 eruptions since 2014
The May 2016 eruption lasted 27 hours producing 0.5 Mm$^3$ of lava flow
InSAR Data provide high spatial resolution

May 2016:
- 6 interferograms
(Sentinel et Cosmo Sky Med)
along 4 different LOS:
ascending and descending

Sentinel Ascending 19/04 – 06/06

Sentinel Descending 20/04 – 07/06
InSAR Data provide high spatial resolution

May 2016:
- 6 interferograms
(Sentinel et Cosmo Sky Med)
along 4 different LOS:
ascending and descending

Sentinel Descending 20/04 – 25/05

Sentinel Descending 25/05 – 07/06
GNSS Measurements provide high temporal resolution
How to combine spatial and temporal information from InSAR and GNSS?
Inversion of ground deformation data

Forward modeling: Mixed Boundary Elements Method (Cayol and Cornet, 1997)
→ Topography
→ Complex fracture

Hypotheses:
→ Linear elasticity
→ Homogeneous and isotropic medium

Non linear Inversion:
Neighbourhood Algorithm (Sambridge, 1999)
Minimizing cost function

\[ U = (d_o - Gm)^T C_d^{-1} (d_o - Gm) \]
Intrusion geometry from Inversion of 4 SAR images

A Sill turning into a Dike
Volume 2.5Mm³
Two model families - same misfit

Model F1
Inv 04a

Model F2
Inv 02a

Eruptive Fissure

Dolomieu Crater

North (km)

Elevation (m)
Two model families - same misfit

Model F1
Inv 04a

Model F2
Inv 02a

Eruptive Fissure

Dolomieu Crater

Misfit

Time (h)

0 0.01 0.02 0.03 0.04

20 21 22 23 0 1 2 3

35 30 25 20 15 10 5

Ellipse
Projected Circle F2
Projected Circle F1
Subgraph F2
InSAR provides geometrical \textit{a priori}

Projected Disk

Subgraph
GNSS temporal information helps solving modeling ambiguities
A step-wise lateral propagation of a single small batch of magma disconnected from its feeding reservoir.

- Mean horizontal velocity: $0.6 \text{ m.s}^{-1}$
- Max horizontal velocity: $2 \text{ m.s}^{-1}$

Quick lateral propagation, arrest then vertical propagation
Conclusions

Methods

- InSAR provides high spatial resolution => geometrical a priori required for GNSS inversion
- GNSS discriminates between families of equally likely models => timing
- Advantages of both datasets characteristics.

Process

- A small amount of magma was trapped into a sill (*preexisting discontinuity ?*)
- External change of the stress field (*east flank sliding ?*)
- Internal change of buoyancy (*gas accumulation ?*)
Thanks!


An atypical seismic crisis starts on May 25, 2016

- A long crisis: 8h25min
- An eruptive vent not so far: 2.8km
- 2 peaks of seismic activity
An atypical seismic crisis starts on May 25, 2016

Why is the magma trapped for 5h before erupting?
An atypical seismic crisis starts on May 25, 2016

What finally triggered the eruption?